An Academic-Industrial Collaboration:
Prof. Brian Benicewicz of Rensselaer Polytechnic Institute and the University of South Carolina
and
Dr. Gordon Calundann of Celanese Corporation, Pemeas GmbH and BASF

In a way, the long and successful Benicewicz-Calundann collaboration began in August of 1974. Brian Benicewicz was still a student, and eventually earned his doctorate in polymer science at the University of Connecticut while Gordon Calundann was seeking polymers at the Celanese Research Company, Summit, NJ, that might be useful as very high performance tire cord. At that time, inspired by the first report of a thermotropic polyester (Tennessee Eastman), Dr. Calundann invented the first of a series of thermotropic liquid crystalline wholly aromatic polyesters. The polymers showed immediate promise as both high performance fibers and engineering plastics and Dr. Calundann was asked to assemble and lead a team to fully develop the technology underlying the new materials and provide Celanese with comprehensive and thorough patent protection.

Dr. Benicewicz, a freshly minted University of Connecticut PhD, became a member of that pioneering team in 1980. For the next three and half years Drs. Calundann and Benicewicz worked closely together and with the team to build a formidable patent grid and define the process and technologies that enabled Celanese to commercialize these new materials. Today, the Vectra® brand of liquid crystalline polymers, manufactured by Celanese Corp. and a Celanese JV, Polyplastics Ltd. of Japan, used in a range of electronic, medical and industrial applications, is by a wide margin the worldwide market leader in this class of engineering plastics. Those early years also produced Vectran® fiber, now made by Kuraray Corp., now used in many cord and fabric products needing high strength, stiffness and cut resistance. Given these properties, Vectran® was selected by NASA for use in the 1997 Pathfinder missions to Mars and was again chosen for the 2003 US and British Martian landings. Worldwide sales of Vectra now exceed 300 million dollars a year.

Dr. Benicewicz left Celanese in 1983 for a position at Johnson & Johnson. Perhaps unrecognized at the time, a long-term productive working relationship, an R & D collaboration with an industrial bias had been forged between Drs. Benicewicz and Calundann during those years of Vectra® and Vectran® commercialization. This working relationship would arise again many years later in an entirely new technology and as a true academic-industrial cooperation.

For the next 18 years Drs. Benicewicz and Calundann kept their collaboration alive albeit on a simmer with frequent polymer science discussions at technical conferences. One notable reunion was the ACS meeting in New Orleans in 1996 when Dr. Calundann received the ACS Award in Industrial Chemistry for his invention of the liquid crystalline polymers used in Vectra and Vectran. Drs. Benicewicz and Calundann reminisced on the 'old days' and with the benefit of hindsight, realized that the microelectronics revolution that transpired over the intervening period was in part made possible by the availability of liquid crystalline engineering plastics; with Vectra® engineering resins clearly the market leader. Dr. Benicewicz would go on to spend a large piece of his career at the Los Alamos National Laboratory researching LCPs and other high performance polymers. In 1998, Dr. Benicewicz accepted a full professorship and head of the Polymer Synthesis Center at Rensselaer Polytechnic Institute in Troy, NY. The Benicewicz-Calundann academic-industrial cooperation begins with this career change. Dr. Calundann remained at Celanese rising to the dual title of Research Director and Senior Research Fellow.

Coincidentally also in 1998, Celanese made the decision to close the lab at Summit and Dr. Calundann, before taking early retirement, saw an opportunity to help equip the fledgling labs of Prof. Benicewicz during his first year at RPI. Approximately 1.5 million dollars of redundant lab equipment was subsequently donated to the care of Prof. Benicewicz to help kick-off his RPI research program. The following year Dr. Calundann, now an advisor to Pemeas GmbH of Germany, was given access to a 1.8 million dollar budget and asked to establish research collaborations in the US in the field of electrolytic membranes based on polybenzimidazole (PBI) for fuel cell application. At the time, Pemeas was a unit of Celanese AG of Frankfurt, Germany. The cooperation envisioned by Pemeas would involve PBI polymer synthesis, membrane and membrane electrode assembly (MEA) fabrication as well as MEA electronic performance testing. Dr. Calundann understood that all of these research components would be best done 'under one roof', and further that the necessary test equipment would be both elaborate and expensive, and that Prof. Benicewicz at RPI was the person to guide the university half of the program. This was to be a major long-term research and development cooperation and such a collaboration would require serious financial support and close, prolonged communication and face-to-face interaction. Subsequently, Dr. Calundann convinced Pemeas to allot a 1.2 million dollar initial funding to RPI under the administration of the Benicewicz research group and some 50 kilos of tetraaminobiphenyl monomer with a value of about $500K. Thus, an intense well-funded cooperation began along with biweekly visits to RPI by Dr. Calundann and with frequent visits by scientists from the Pemeas lab in Frankfurt as well as reciprocal visits by Prof. Benicewicz to Frankfurt.

At that time MEA state of the art, that is, an alternative energy technology designed to generate electricity from hydrogen and oxygen was primarily done at about 80°C using wet Nafion® fluoropolymer as the proton conducting component in the MEA. This approach has the serious disadvantage of platinum deactivation when using lower cost hydrogen with a carbon monoxide impurity. Also, heat produced at this temperature is less useful than it could be if captured at higher temperatures. The RPI/Pemeas (Celanese) program would focus on high temperature MEA technology using PBI and phosphoric acid as electrolyte. This approach could lead to much cheaper fuel cells since these are operable at higher temperatures and impure hydrogen fuel can be used as catalyst poisoning is avoided since PBI MEAs operate in the 140-180°C range.

The Benicewicz RPI team together with Dr. Calundannn and Pemeas working together came up with a major breakthrough in membrane synthesis and fabrication in 2000. The initial membrane process, entirely developed at RPI, offered flexibility in membrane manufacture with a major saving in cost. Numerous joint patents were filed and within a relatively short time, this process was adopted by Pemeas and put into manufacture at a pilot facility in Frankfurt. Further, RPI played a significant role in the development of new PBI polymer compositions, MEA fabrication methods and testing protocols with membranes made from this new proprietary process. Prof. Benicewicz, RPI (and later USC) and Pemeas (and later BASF) became widely recognized as leaders in high temperature MEA technology.

As a result of this joint research, Pemeas GmbH was successfully spun-off to a group of international investors in 2003, and as the MEA business and reputation of the new startup increased, it attracted the attention of BASF of Ludwigshafen, Germany. By this time a second PBI membrane and MEA pilot facility was opened in New Jersey to produce the Celtec® MEA. BASF recognized the unique advantages of the Pemeas technology and acquired Pemeas GmbH in 2006. Also by then, Prof. Benicewicz had accepted an endowed chair position at the University of South Carolina, but his key interaction with this program and Dr. Calundann, now CTO of the newly formed business unit of BASF, continued without interruption. During this period the Benicewicz Group at USC expanded the application of the PBI-based MEAs into hydrogen purification and now both PBI-based technologies, high temperature MEAs for fuel cells and high temperature MEA hydrogen purification, are under active development by BASF in Germany and currently used in commercial fuel cell devices in both Europe and the U.S.

Dr. Calundann retired from BASF in 2011 but Prof. Benicewicz and his team at USC have continued this extraordinary academic-industrial cooperation, now with BASF, to the present day: A cooperation that really began in 1980.